# CHAPTER 4

# DESIGN FOR CRACK CONTROL

**4-1. Introduction.** This chapter provides criteria and methods to control cracking in concrete and brick masonry walls, composite walls, and anchored veneer wythes. Normally, cracking in masonry results from shrinkage in concrete masonry unit construction and expansion in brick masonry unit construction. Uncontrolled cracking is a significant problem in the masonry industry. Cracking is controlled by proper placement of joints, proper material selection, and by steel reinforcement, or a combination thereof. Although the cracking of masonry is not normally a structural design consideration, the locations of joints placed in masonry walls to control cracking can affect the structural performance of the wall. The crack control criteria contained herein is based on locations where environmental changes (temperature and moisture fluctuations) are large. When supported by successful local practice; the designer may deviate from the joint locations, material selections, and reinforcement criteria contained in this manual. Locations and details of control joints, bond beams, brick expansion joints, and structural expansion joints will be shown on the contract drawings on both plan and elevation views.

**4-2. Concrete masonry walls**. Cracking of concrete masonry walls is generally caused by shrinkage due to moisture loss in the units. Methods used to control cracking in concrete masonry structures are materials specifications to limit the drying shrinkage potential, control joints (CJ's) to accommodate movement, and reinforcement to control crack size and location.

*a. Material specifications.* The type of unit to be used in all construction will be ASTM C 90, moisture controlled, type I, units. Type II units, which have no moisture control, will not be used. The ASTM C 90 standard provides limits on moisture content for moisture controlled units depending on linear shrinkage potential and average annual relative humidity at the place where the units will be installed. For example, in an area where the average annual relative humidity is 50 to 75 percent and the linear shrinkage potential of the unit is 0.03 percent, the units should be delivered to the site with a maximum moisture content of 40 percent. Units with a linear shrinkage potential of 0.045 to 0.065 percent, delivered to the same site, should have a maximum moisture content of 30 percent. The purpose of this part of the standard is to limit the shrinkage of the unit in the wall to a level sufficient to control cracking. Masonry units delivered and stored at the site should be protected from rain and snow, which would increase their moisture content.

*b. Control joints.* To control shrinkage cracking, control joints should be placed and spaced to divide walls or wythes into a series of rectangular panels. Control joints should also be placed in areas of high stress concentration where cracking is most likely to occur. Normal spacing and desirable locations for control joints are noted in table 4-1. Control joints should not be located at openings due to construction and performance problems and minimum reinforcement requirements. For structural walls, the minimum reinforcement around openings is given in chapter 5. For non-structural partitions, the minimum reinforcement around openings will consist of one No. 4 bar at each side and at the top and bottom of each opening. Reinforcing bars will extend 24 inches beyond the edge of the opening.

*Table 4-1. Recommended control joint spacing [(a)]*

| VERTICAL SPACING OF JOINT REINFORCEMENT WITH 2-#9 WIRES[(b)] (IN) | MAXIMUM RATIO OF PANEL LENGTH TO WALL HEIGHT (L/H)[(c)] | MAXIMUM SPACING OF CONTROL JOINTS[(d)] (FT) |
|---|---|---|
| None[(e)] | 2 | 18 |
| 16 | 3 | 24 |
| 8 | 4 | 30 |

[(a)]based on moisture-controlled, type I, concrete masonry in intermediate humidity conditions (ASTM C 90). The designer should adjust the control joint spacing for local conditions. The recommended spacing may be increased 6 feet in humid climates and decreased 6 feet in arid climates.

[(b)]Joint reinforcement will he cold-drawn deformed wire with a minimum 9 gauge longitudinal wire size.

[(c)]L is the horizontal distance between control joints. H is generally the vertical distance between structural supports.

[(d)]The spacing will be reduced approximately 50% near masonry bonded corners or other similar conditions where one end of the masonry panel is restrained.

[(e)]Not recommended for walls exposed to view where control of cracking is important.

Recommended control joint locations

a. At regular intervals as noted in table above.

b. At changes in wall height or thickness. (This does not include at pilasters.)

c. Near wall intersections in "L", "T", and "U" shaped buildings at approximately 50% of the spacing required above.

d. At other points of stress concentration.

e. At control joints in foundation walls and in floors that support masonry walls.

(1) A keyway or interlock will be provided across control joints as a means of transferring lateral shear loads perpendicular to the plane of the wall. Transfer of bending moments or diagonal tension across control joint keyways or interlocks should not be assumed. Control joints should be weathertight.

(2) Control joints in concrete masonry unit walls will be continuous and vertical. Control joint details must provide an uninterrupted weak plane for the full height of the wall, including intermediate bond beams and masonry foundation walls. However, reinforcing steel in structural bond beams must be continuous through control joints. Control joints need not extend into reinforced concrete foundation walls.

(3) Control joints divide walls into panels which are separate structural elements. Hence, locations of control joints effect the relative rigidity of wall panels and, in turn, the distribution of lateral (seismic or wind) forces and the resulting unit stresses. Therefore, adding, eliminating or relocating control joints, where the lateral load resisting system is sensitive to control joint location, will not be permitted once the structural design is complete.

(4) The control joint location criteria above applies to all walls exposed to view where control of cracking is important. For walls not exposed to view, a control joint spacing of four times the diaphragm to diaphragm height or 100 feet, whichever is less, may be used.

*c. Joint Reinforcement.* Joint reinforcement distributes local temperature and shrinkage stresses and allows a greater control joint spacing to be used. Joint reinforcement spacing as it relates to control joint spacing is provided in table 4-1. It is recommended that all walls exposed to view, where control of cracking is important, have joint reinforcement spaced not more than 16 inches on center. Joint reinforcement will be terminated at control joints.

*d. Control joint detailing.* Control joints are either flush, raked, or raked and sealed depending on specific requirements as given in the guide specifications.

**4-3. Brick walls.** Cracking in brick masonry generally results from a combination of expansion due to moisture absorption by the brick and thermal expansion of the brick wall. Detailing of brick masonry must allow for both horizontal and vertical expansion of the wall or wythe panels. Crack control in brick walls is accomplished with brick expansion joints (BEJ's). The allowance for expansion and the criteria to establish joint spacing given herein may be adjusted when climatic conditions warrant.

*a. Brick expansion.* The total unrestrained expansion of clay brick masonry walls, $W_x$, may be estimated from the following formula:

$$W_x = [\epsilon_A + \epsilon_T(\Delta T)(L)] \qquad \text{(eq 4-1)}$$
$$= [0.0003 + 0.000004(\Delta T)](L)$$

Where:

$\epsilon_A$ = The coefficient for volume change due to moisture expansion. It will be assumed equal to 0.0003 times the wall length.

$\epsilon_T$ = The thermal coefficient of expansion for clay or shale brick. It will be assumed equal to 0.000004 per unit length per degree Fahrenheit.

$\Delta T$ = The maximum temperature differential expected during the life of the structure, degrees Fahrenheit. $\Delta T$ should not be assumed less than 100.

L = The length of wall between expansion joints, inches.

*b. Vertical expansion joints.* Crack control for horizontal expansion in brick is mainly accomplished by the proper placement of continuous vertical BEJ's. BEJ's should be placed and spaced to divide a wall into a series of rectangular panels to control cracking. Since the backer rod and sealant used for sealing vertical BEJ's are assumed to be only 50% compressible, the computed total expansion value, $W_x$, must be multiplied by two to obtain the required joint width. The maximum vertical BEJ spacing for various expansion joint widths, based on $\Delta T = 100°$F, along with desired joint locations of vertical BEJ's are listed in table 4-2. BEJ's in parapet walls will be at one half the spacing of the supporting walls below. Vertical BEJ's do not transfer bending moment or shear and must occur at locations where no load transfer is required.

*Table 4-2. Maximum spacing of vertical expansion joints in brick walls, $\Delta T = 100°$ F*

| EXP. JT. WIDTH (IN) | $W_x$ (IN) | MAX. SPACING OF BEJ's[a] (FT) |
|---|---|---|
| 3/8 | 3/16 | 22 |
| 1/2 | 1/4 | 30 |
| 3/4 | 3/8 | 44 |
| 1 (MAX) | 1/2 | 60 |

[a]Provide expansion joints at 6 to 10 feet from corners.

Recommended vertical BEJ locations

a. At regular intervals as noted in table above.

b. At changes in wall height or thickness.

c. Near wall intersections in "L", "T", and "U" shaped buildings at approximately six to ten feet from corners.

d. At other points of stress concentration.

e. At edges of openings.

*c. Horizontal expansion joints.* Crack control for vertical movement in brick walls is accomplished with horizontal BEJ's. The minimum horizontal joint width will be ⅜ inch. This minimum joint width will accommodate movement for most buildings in normal situations. Designers should be aware of building effects, such as, elastic shortening and creep. These effects may require a greater joint width. Recommended horizontal BEJ joint locations are:

(1) Under shelf angles and lintels which are supported by back up wythes.

(2) At each floor level to multi-story buildings.

(3) At points of stress concentration due to vertical movement restraint.

*d.. Reinforcement.* BEJ locations and spacing are not adjusted when joint reinforcement is used. However, joint reinforcement is recommended as it will provide greater resistance to cracking due to environmental conditions.

*e. Joint detailing.* Expansion joints are sealed with backer rod and mortar colored sealant. Joints as small as ⅜ inch may be used if architectural considerations dictate. The joints must be kept clear of all material other than the backer rod and sealant. Foam rubber fillers are not permitted in brick expansion joints.

**4-4. Anchored veneers**. Anchored brick and concrete masonry unit veneers must be isolated on three sides from the back-up wythe. Since the veneer is isolated from the back-up wythe, concrete masonry unit control joints or brick expansion joints in the veneer need not aline with the joints in the back-up wythe.

*a. Brick masonry anchored veneer.* Joint spacing and locations and other requirements are as described in paragraph 4-3 and table 4-2.

*b. Concrete masonry anchored veneer.* It is recommended that all concrete masonry anchored veneer contain joint reinforcement at not more than 16 inches on center. Control joint spacing and locations will be according to paragraph 4-2 and table 4-1, except that control joints at openings should be similar to brick veneer. Control joint details will be similar to brick veneer, i.e., both vertical and horizontal joints will normally be %-inch wide and closure will be with a backer rod and sealant.

**4-5. Composite walls**. Where both wythes of the composite wall are concrete masonry, the designer will apply the prescribed crack control procedures for concrete masonry to each wythe. Where brick and concrete masonry units are used together in composite type walls, control joints and expansion joints must extend through the full thickness of the wall wherever either one is required. Brick expansion joints also serve the requirements of control joints but control joints do not serve as expansion joints.

**4-6. Isolation of nonstructural partitions.** When a masonry wall is not a part of the lateral or vertical load resisting system it will be isolated. Isolation joints will be provided between the partition and the frame, structural walls, or roof, etc., to prevent loading the partition.

**4-7. Shelf angles**. Masonry walls and veneers in multistory buildings or in buildings with a large number of openings are often supported on shelf angles at intervals of one or two story levels. The shelf angle will be secured against rotation and against deflections over $^{1}/_{16}$-inch. A ½-inch space between the ends of shelf angles will be provided to allow for thermal expansion. Shelf angles will be mitered and made continuous at the corners of the building.

**4-8. Other than running bond masonry.** In addition to the requirements in the previous paragraphs, all walls or wythes placed in other than running bond will have a minimum area of horizontal reinforcement. The minimum reinforcement will be 0.0007 times the vertical cross sectional area of the wall. Reinforcement may be placed in bed joints or in bond beams or both.